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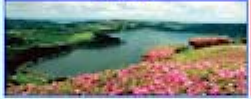

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BENDING RESISTANCE OF PARTIALLY ENCASED BEAMS AT ELEVATED TEMPERATURE: ADVANCED CALCULATION MODEL

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ABSTRACT

Partially Encased Beams (PEBs) are composite steel and concrete elements in which the web of the steel section is encased by reinforced concrete. The experimental investigation of the bending resistance was already verified in fire and under elevated temperature (Paulo A. G. Piloto *el al.*, 2013a) (Paulo A. G. Piloto *el al.*, 2013b). The three-dimensional finite element solution, with precise detail of each component (steel profile, reinforcement, stirrups and concrete) was used to determine the bending resistance under three point bending configuration. Four temperature levels were tested (20, 200, 400 and 600 ºC) and three lengths were considered (2.5, 4.0 and 5.5 m), using three different cross section types, based on the dimensions of IPE100, IPE200 and IPE300 steel profiles. Two distinct types of welded stirrups were simulated (PEBA with "C" shape stirrups welded to the web and PEBB with "I" shape stirrups welded to the flange). The solution method is incremental and iterative (arc length), based on geometric and material non-linear analysis (ANSYS), using reduced integration method. Results are in accordance to the new formula presented (P. M. M Vila Real *et al.*, 2004) and adapted to partially encased beams. The bending resistance was not significantly influenced by the type of welded stirrup.

Keywords: Partially Encased Beams, Numerical simulation, Fire, Elevated temperature, Composite Steel and Concrete.

INTRODUCTION

A total of 72 models were simulated, showing conservative results with respect to the simple calculation method of EN1994-1-2 (CEN, 2005b). The bending resistance of the numerical results was determined for different force events (The proportional limit force F_p; the force F_y using the intersection method between two straight lines drawn from linear and non-linear interaction of the vertical displacement; the load event for the displacement limits $F_{L/20}$ and $F_{L/30}$; and the maximum load level for the asymptotic behaviour of lateral displacement F_u). Table 1 presents the main characteristics of each beam under simulation also with mesh information. Three-point bending test was considered. Special boundary conditions to simulate fork supports were defined. Each simulation was performed using an incremental and iterative process to define the bending resistance.

MATERIALS AND METHODS

The model considers perfect contact between steel and concrete. The material models are in accordance to EN 1992-1-2 (CEN, 2004) and 1993-1-2 (CEN, 2005b), assuming elastic and plastic behaviour. A convergence test was performed to determine the adequate mesh size. Solid hexahedral finite elements with eight node were used for steel (SOLID 185) and concrete (SOLID 65). The member imperfection was based on the first mode elastic bucklinf shape, also performed with finite element method (ANSYS), using an equivalent imperfection maximum value L/600.

Table 1 - Characteristics of partially encased beams.

Id.	Reinf. [mm]	Stirrups Dim. [mm]	Stirrups shape	stirrups spacing [m]	Lt [m]	Ls [m]	Nodes Number	Elements Number
PEBA100_2,4F	Ø10	Ø6	C	0,167	2,5	2,4	187473	171648
PEBA100_3,9F	Ø10	Ø6	C	0,167	4,0	3,9	290301	266112
PEBA100_5,4F	Ø10	Ø6	C	0,167	5,5	5,4	404415	370944
PEBA200_2,4F	Ø12	Ø6	C	0,100	2,5	2,4	200165	183600
PEBA200_3,9F	Ø12	Ø6	C	0,100	4,0	3,9	321195	294984
PEBA200_5,4F	Ø12	Ø6	C	0,100	5,5	5,4	439565	403920
PEBA300_2,4F	Ø20	Ø6	C	0,171	2,5	2,4	197715	182240
PEBA300_3,9F	Ø20	Ø6	C	0,171	4,0	3,9	312375	288320
PEBA300_5,4F	Ø20	Ø6	C	0,171	5,5	5,4	427035	394400
PEBB100_2,4F	Ø10	Ø6	I	0,167	2,5	2,4	187473	171648
PEBB100_3,9F	Ø10	Ø6	I	0,167	4,0	3,9	290301	266112
PEBB100_5,4F	Ø10	Ø6	I	0,167	5,5	5,4	404415	370944
PEBB200_2,4F	Ø12	Ø6	I	0,100	2,5	2,4	257985	238000
PEBB200_3,9F	Ø12	Ø6	I	0,100	4,0	3,9	321195	294984
PEBB200_5,4F	Ø12	Ø6	I	0,100	5,5	5,4	439565	403920
PEBB300_2,4F	Ø20	Ø6	I	0,171	2,5	2,4	197715	182240
PEBB300_3,9F	Ø20	Ø6	I	0,171	4,0	3,9	312375	288320
PEBB300_5,4F	Ø20	Ø6	I	0,171	5,5	5,4	427035	394400

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